

The Effect of Model Design, Cushion Construction, and Thin Pressure Mats on Pressure Measurement

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Introduction

- Wheelchair users are commonly at risk for pressure ulceration because of sensory and/or mobility impairment

(Bouten et al, 2003; Barbenel, 1991)

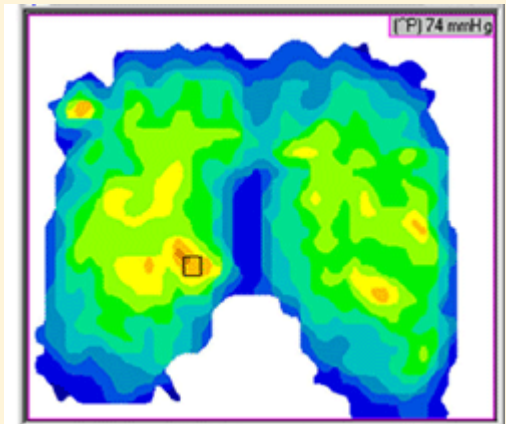
- Wheelchair cushions attempt
 - To reduce and distribute forces on skin
 - To decrease the chances of skin breakdown

(Sprigle, Dunlop, Press 2003)

- Pressure mapping used clinically and in research to evaluate, classify, and select cushions

- Clinically – array of sensors in a thin mat

(Swain and Bader 2002; Ferguson-Pell and Cardi 1993)



Purpose

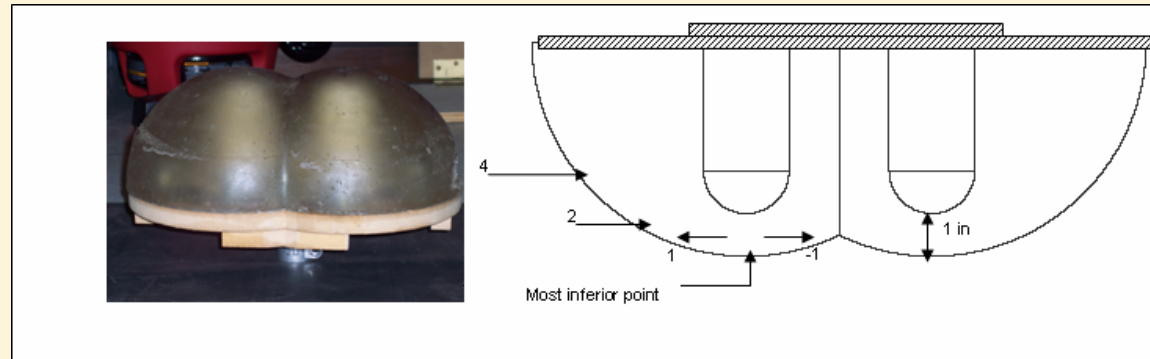
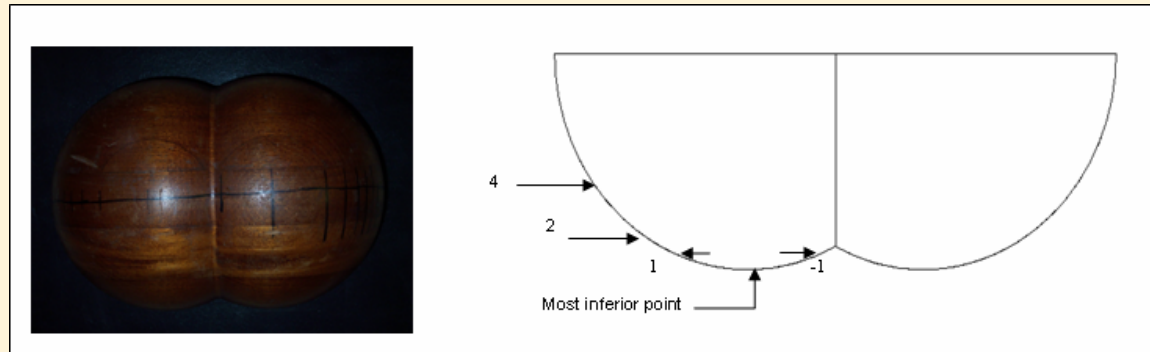
- Explore changes in interface pressure, envelopment, and immersion caused by
 - Addition of a pressure sensing mat
 - Cushion construction
 - Indenter model design

Hypotheses

1. Interface pressure and envelopment vary by cushion construction
2. Interface pressure and envelopment differ across model design

Model Design

- 2 buttock models:
 - rigid and gel
 - 36 cm wide
 - 11 cm ischial spacing
 - Gel model has imbedded rigid cylinders to model the IT's.
- 5 points of interest
 - Defined by vertical relationship to IT



Pressure Sensors

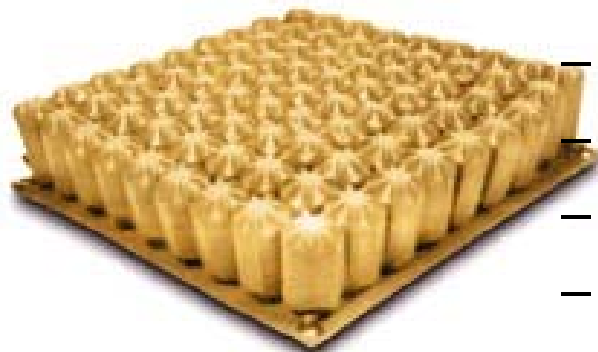


- Custom FSA Individual Pressure Sensors
 - active area = $.3\text{in}^2$ each
 - 2 mounted per site
 - Two sensor configurations
- Calibration performed before each data collection session
 - $<10\%$ error at 100 mmHg

Cushion Construction

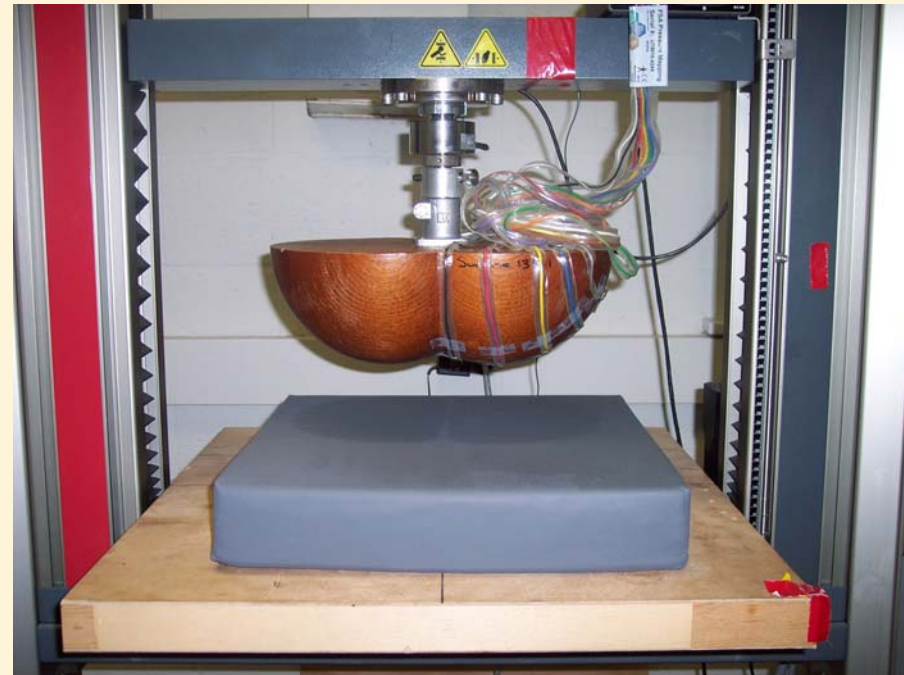
- 7 cushions with different design features:

- Action XAct – Foam/Elastomer
- J2 Deep Contour – Foam/Viscous Fluid
- Otto Bock Cloud – Foam/Viscous Fluid
- Star – Air
- Tempermed – Viscoelastic Foam
- Flat 3" thick HR 45 foam
- HR 45 foam segmented into 2"x2" squares extending 1" into the 3" block



Methods

- Model affixed to Zwick materials testing machine
- Preload to 550 N for 120 seconds
- 3 min rest
- 500 N load for 120 sec
- Pressure data captured by FSA sensors.
- 3 trials per condition
 - 7 cushions x 2 models



Variables

- Magnitude
 - Relative variables are more repeatable

$$Total - 1\sigma Ratio = \frac{[(-1cm) + (IT) + (1cm)]_{test}}{[(-1cm) + (IT) + (1cm)]_{ref}}$$

- Envelopment
 - Ideal envelopment would result in even pressure across the model
 - *Parity/COV*: measures equality of pressure measured. Closer to 0 indicates more equality and better envelopment.

$$Parity = \frac{(1cm) - (-1cm)}{(1cm) + (-1cm)}$$

$$COV = \frac{\text{Standard Deviation}}{\text{Average}}$$



Results - Magnitude

	Jay Deep	Action	Star	HR Segmented	Tempermed	Cloud
Rigid	0.59	1.11	0.58	1.10	0.94	1.11
Gel	1.00	0.88	1.67	0.87	0.99	1.82
Difference	0.42	-0.23	1.09	-0.23	0.05	0.71

Table 1: Total -1 to 1 ratio by cushion Value higher than 1 means test cushion magnitude>reference foam

- Significant difference between models for 5 cushions
- Overall, magnitude higher with the gel model
 - Significant drop with Action and Segmented HR

$$Total -1to1 Ratio = \frac{[(-1cm) + (IT) + (1cm)]_{test}}{[(-1cm) + (IT) + (1cm)]_{ref}}$$



Red numbers indicate significant difference, $p < .05$.

Results - Envelopment

	HR Ref Foam	Jay Deep	Action	Star	HR Segmented	Tempermed	Cloud
Rigid	0.14	0.03	0.40	0.14	0.19	0.64	0.39
Gel	0.09	0.10	0.10	0.08	0.07	0.31	0.01
Difference	-0.05	0.06	-0.30	-0.06	-0.12	-0.33	-0.38

Table 2: Parity 11 by cushion

- Significantly greater envelopment with gel model for 5 cushions and overall
 - Pressure at the 2 sites is more equal with the gel model
 - Jay Deep and Star → no difference between models
 - Both had very good envelopment with both models
- Shape of the indenter-cushion interface differs across models



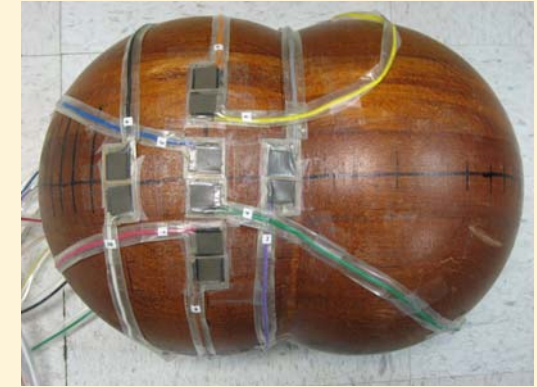
Red numbers indicate significant difference, $p < .05$.

$$Parity = \frac{(1cm) - (-1cm)}{(1cm) + (-1cm)}$$

Results - Envelopment

	Foam	Jay Deep	Action
Rigid	42.16%	17.47%	57.31%
Gel	5.26%	28.65%	25.72%
Difference	-36.90%	11.18%	-31.59%

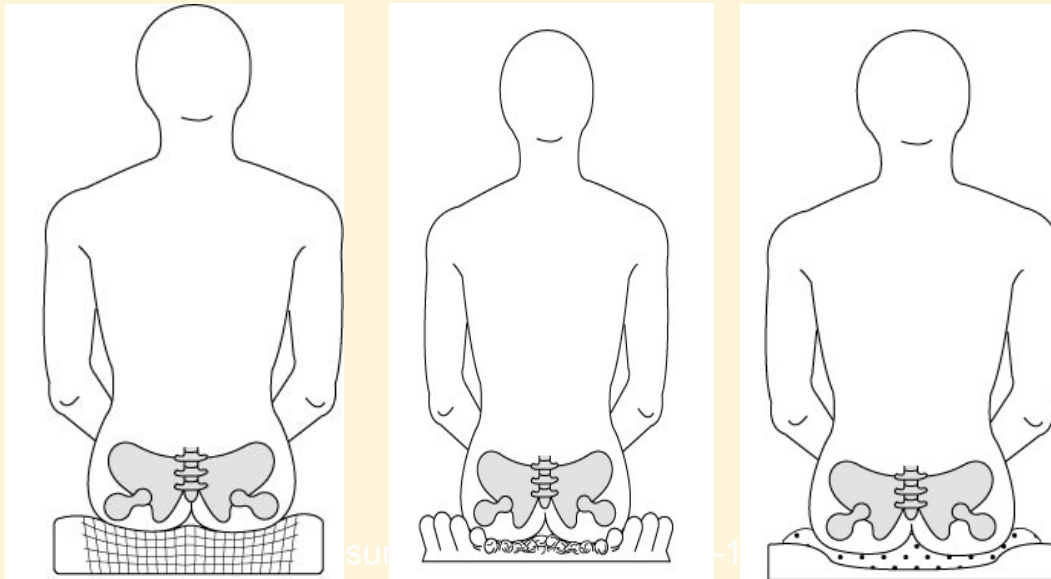
Table 3: COV of all 5 sensors in 2nd sensor configuration



- Overall 5 sensors are closer to the same value with the gel model
- Jay Deep envelopment significantly worse with the gel model
 - Jay Cushion has bladder with highly displaceable viscous fluid

Discussion

- For all variables, there was a statistically significant interaction between model and cushion
 - The difference between the models changes depending on the cushion
- Cushions deform under load
 - Each cushion deforms differently
- Gel model deforms under load
 - Deformation influenced by cushion stiffness
- Deformation of model and cushion not necessarily consistent every loading
- Result → Volatility in pressure measurement
 - Models affect measured cushion performance



Conclusion and Significance

- Different model materials affect pressure magnitude and envelopment.
 - Cushion construction influences the difference
- Standardized tests use models to measure cushion performance
 - Tests must be repeatable —→ inconsistent deformation of cushion and/or model can cause volatility, lowering repeatability
 - Tests must be valid —→ further exploration on which model behaves like human tissue